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THE PRODUCTION OF PETROLEUM IN GREAT BRITAIN

By J. S. PARKER, M.A., B.Sc., F.Inst.Pet.

IN discussing the production of petroleum in Great Britain it would be appropriate to commence the story with the first records of the observation of oil in the country as these were not without their interest or their humour. Print limitations, however, decree otherwise and the reader who may desire more complete information on the "bottle stage" of petroleum in Great Britain is recommended to consult the numerous articles which have appeared on this subject. As illustrative of the period, however, a few extracts are given.

About 1740 it was found that seepage oil burned so fiercely that eggs could be boiled over the flame. This discovery does not appear to have been developed. Possibly eggs were the difficulty.

About 1840 oil made its presence known to the coal miners. A stream of oil flowed into the top of a coal working. This oil was collected and forwarded to James Young's refinery in the north, where it was processed, on a commercial scale, into burning oil, lubricating oil and paraffin wax. As the total production is recorded as seven to ten barrels a day the term "commercial scale" must be considered in accordance with the date and not in accordance with a present day conception of that term.

These petroleum evidences in coal mines have been numerous and persist to date. It was stated, prior to commercial production of petroleum, that the most promising oil-bearing zones in

Great Britain lie below valuable coal measures. Commercial production of petroleum to date has been obtained in close proximity to coal measures.

It was not until 1864 that an old friend appears—the seepage oil which was done up in bottles and became a very well-known application for sprains and rheumatism.

These few extracts from many similar recorded evidences would illustrate the fact that as regards actual evidence of petroleum, in the form of seepage and oil shows, Great Britain was no less well provided than other nations which have developed considerable petroleum resources. They also illustrate the fact that Great Britain was in no way behind other countries in groping her way forward in the development of this raw material. It is indeed probable that James Young's commercial lines were well in advance of the petroleum industry's technique at that time. Where Great Britain did lag was in her negligible efforts to develop commercial production. With, in those days, an ample coal supply and no internal combustion engine, the development urge was not present.

One significant item appears in these bottle stage records. When a test bore was drilled at Kelham, near Newark, in search of coal measures, the bore penetrated a loose brownish sandstone 15 feet thick, at a depth of 2,452 feet. Oil flowed regularly during eleven months at five to six gallons a day. During the World War II years, Kelham became a producing field second only to the Eakring field.

A near slogan which had widespread publicity immediately following World War I was that "The Allies floated to victory on a wave of oil". The significance of petroleum had become apparent. Development urge became transformed overnight into development necessity. The Government became financially interested. Parliament in 1918 voted £1,000,000 to be placed at the disposal of bona fide concerns for petroleum development purposes.

£500,000 was spent. Hardstoft No. 1 was the only producing result. All other holes, apart from gas or oil shows, were dry. As a total production of around six barrels a day was considered an uneconomic return for the capital expended further drilling was stopped at this stage. Development sank back into the doldrums.

Hardstoft No. 1 was brought in on May 27, 1919. It produced from a 15-feet thick sandy limestone at a depth of 3,070 feet. Production, averaged over a period of 8½ years, was six barrels a day, which is reasonable if you have enough wells. The oil was of the waxy type which will be more fully described in a later article.

Though Hardstoft No. 1 did not place Great Britain on the map as an oil-producing country, it at least indicated that the possibilities were there, though probably not on the scale which was initially envisaged.

The exploratory drilling of this period was carried out by the Pearson (Lord Cowdray) interests, which had gained considerable experience of this type of work in Mexico. Considering it from present day standards and knowledge, one can realize the difficulties they were up against in their endeavours to obtain commercial production in Great Britain. Geological skill was in its infancy. In the more or less hit-or-miss methods of those days the chance of hitting the large Mexican pool was considerably greater than that of hitting the small pool in Great Britain. Again exploration operations, where the company concerned thought in terms of miles, were restricted when dealing with British land owners who thought in terms of acres and possessed the sub-surface rights.

In 1934 the Government passed the Petroleum (Production) Act which remedied this position. The petroleum sub-surface rights were transferred to the State and entry on to land for the

purpose of petroleum exploration and exploitation was facilitated. The resultant drive derived considerably from the enthusiasm and encouragement of the first Lord Cadman.

The majority of the major oil companies took an interest in this exploration work. Test holes were drilled in Scotland and in England, on what were considered to be the most favourable sites. Just prior to World War II the majority of the most favourable sites had been drilled up, without result from the commercial production standpoint.

Out of all the companies engaged on this exploratory work only the Anglo-Iranian Oil Company struck commercial production. The discovery wells were drilled in 1939 and were located at Formby, near Liverpool, and Eakring, near Newark in Nottinghamshire. As has been indicated above, both were on the secondary list of evidences for investigation. Owing to the outbreak of war shortly after the discovery of commercial production these operations were not officially disclosed, though there were plenty of rumours, until towards the end of 1944.

Commercial Production

Prior to War I production was at the bottle stage. Between the First and Second World Wars production was at the barrel stage as it was limited to one well at Hardstoft which was capable of producing a few barrels a day. Extensive drilling operations towards the end of this period did not result in additional sources of supply. In view of its outstanding position during this period and the fact that it did actually contribute to commercial production during World War II, Hardstoft would appear to qualify for inclusion under this heading.

Hardstoft

In 1936 Lord Cadman referred to Hardstoft in his Presidential Address to the Institute and made the significant remark that the origin of this source of oil had never been determined.

In 1937 the Hardstoft well was taken over by the Anglo-Iranian Oil Company and put into satisfactory mechanical condition. It was deepened into the limestone to see if increased production could be obtained and to check for the level of the water below the oil.

Hardstoft was within the operational orbit of Eakring and it was operated in conjunction with that field during World War II. The well was tickled up by the various production-increasing methods now available and the barrels per day output was increased. The result was that this well, originally drilled in 1919, produced 8,700 barrels of oil during the last war years and contributed a large part of this oil to the war effort. The oil was transported by road tanker to Eakring for rail despatch to the refinery.

The production rate increase was temporary as is generally the case. The well dropped back to its few barrels a day, the oil produced contained increasingly large percentages of water, and towards the end of War II Hardstoft stopped being a contributor to the commercial production of this area.

It is doubtful how far Hardstoft would have been commercial had it not been in proximity to the producing fields in the Eakring area. Its accelerated war effort, resulting in the well more or less going to water, has written it off from this category.

The first stage in the quest for oil in Great Britain by the Anglo-Iranian Oil Company was the search through all the available literature for records of seepages, oil shows, oil indications, and formations suitable for the entrapment of oil. These were checked by the geologists and/or by geological methods and sorted out into test drilling priority, the most favourable indications for oil being at the head of the list. Geological skill has advanced very considerably since the early Hardstoft days but drilling a test hole still remains the only

method of locating the presence of oil in commercial quantity. As has been indicated the test drilling operations on the most favourable sites, i.e., up to immediately prior to World War II, had resulted in a series of dry holes. It was not until 1939, when evidences further down the priority list were being investigated, that oil was struck at Formby.

Formby

Formby is on the northern outskirts of Liverpool, near the coast. The land is, to a large extent, black, peaty and intersected by drainage channels. At one period it was a peat bog. In the geological records there was reference to a seepage in one of these drainage channels though not clearly to a petroleum seepage. When this was investigated by the oil company's geologists it proved to be a typical oil seepage.

Shallow wells were drilled in the vicinity of this seepage and oil was struck at about 100 feet. Twenty-five shallow wells were drilled which served to define the oil pool at about 30 acres in extent. Of these wells twelve gave sufficient production to justify the installation of well pumps.

A second similar oil seepage was later discovered but test drilling in this area resulted in dry holes.

The oil pool under the first seepage, and underlying the peat at 100 feet, produced an oil of a waxy nature typical of a deep-seated origin. Its location was not the mother source. The indications were that the oil had migrated. Again though the defined oil pool was small in area the production from the wells showed little sign of decreasing to the extent anticipated. This appeared to indicate that migration was still in operation.

Test drillings were carried out to find the mother source. In the horizontal these extended towards the coast and inland towards a coal mine but no further oil was discovered. For vertical check a deep drilling rig was set up close to the shallow producing wells. This test well was drilled to 5,885 feet without finding any trace of a deeper oil. At this depth the drilling bit penetrated a hard silicified rock which was sufficiently plastic to defy fragmentation. Rock bits were used up at a fantastic rate to obtain a few inches penetration. Diamond drills, chilled shot, and all other methods of dealing with rock were unsuccessful. Samples of the rock were sent to drilling bit manufacturers to see if they could devise a tool to meet the exceptional conditions. Deep drilling operations came to a standstill. During this period Eakring came into prominence and all effort and material was concentrated on that field. The deep drilling rig was transferred and Formby remains to this day an enigma. The mother source of the oil has never been determined.

The production from the Formby field peaked at about 200 barrels a week and remained remarkably steady throughout War II at 120. Since then there has been a slow decrease to 50 barrels a week at which figure it is producing steadily at present.

The scene shifts to the Sherwood Forest area where there is considerable coal mining activity and where the records indicated the presence of oil shows in the coal mines and during the search for coal measures. There was no doubt about the presence of oil in this area but whether it was present in the form of trapped accumulations was another matter. Geological records indicated that the strata in this area was considerably faulted, i.e., the underground strata was broken and not continuous. Geologists look with disfavour on faults. If there had been an accumulation of oil it would probably have migrated up a fault and disappeared. Thus this area was down the test priority list because of the poor indications of suitable strata conditions for oil accumulation.

The shape of the underground strata was checked by modern methods, mainly geophysical. This survey disclosed the presence of several domes which were aptly described by the personnel concerned, in view of their Iranian experience, as "pimples." In other words the domes were comparatively small. A dome can be compared to an inverted tea-cup. If oil is present then in all probability some at any rate has been trapped in what was the bottom of the tea-cup before it was inverted. These domes were test drilled and oil was struck. As in this case there was no doubt about the oil source the way was open for drilling up the first real oilfield to be discovered in Great Britain. Its scope might be limited when compared with foreign oilfields but it was similar in development requirements.

The main geophysical work carried out in this area was seismographic, which consists in detonating charges of explosive in the ground and calculating the strata depth from the time it takes the sound wave to hit the underground strata, bounce off, and travel back to the receiving set. Mapping by this method was later carried out over a wide area round Newark, the only blanks being in the neighbourhood of aerodromes where the inhabitants were sound sensitive.

Eakring

The discovery well in the Sherwood Forest area was drilled at Eakring which is about ten miles north-west of Newark. Initial commercial production was developed here and though later other small fields were developed in this area the term Eakring tended, incorrectly, to become synonymous with indigenous crude.

In the Eakring area two domes, comparatively close together, were mapped, one at Eakring Field and the other at Dukes Wood, both near the village of Eakring. The countryside here is typically English, hilly, with green fields, orchards, and woods. Drilling operations had thus to be carried out with circumspection to ensure that the rural beauty was not destroyed. In the old days this would have been difficult, as practice then was to remove the landscape and then beautify it with a multitude of derricks. Modern equipment, used with care and judgment, solved this difficulty. As illustrative of this, one well was sited and drilled in a closely spaced apple orchard. All the work involved in taking the rig in, rigging up, drilling, dismantling the rig, taking it out and putting the well on the pump resulted in the necessary destruction of one apple tree and slight damage to one other. A country road running past this orchard traversed part of the oilfield, which is not apparent until one's notice is drawn to the small motor-driven pumping jacks spaced out across the green fields.

Dukes Wood was not so simple in this respect as trees had to be cut to get material on to the sites. A considerable amount of clearing and difficult road making was necessary. This work was done for a short time by the Canadian Road Construction Engineers. As typical of this unit the following story may be told.

The boss and a visitor were on a tour of inspection of Dukes Wood in a Ford V8. Heavy snow was on the ground. Rounding a bend after a downgrade, virgin snow collapsed into an outsize in ruts and the car was bogged properly. It was a busy spot and soon eight or ten men were busily pushing, without effect. A heavy truck hitched on but could not get a grip on the ice. Down the grade came a C.R.C.E. truck. Out jumped a husky individual who took immediate command of the situation. Remarking that it was only a little thing, anyway, he lifted the front and swung the car sideways out of the rut.

The first Eakring well proved production at between 2,000 and 2,500 feet which is a comparatively shallow drilling

proposition. Several separate and independent oilsands were penetrated, one underlying the other. In the central part of the structure four separate oilsands gave production, the main producing horizon being a hard sandstone varying between 50 and 100 feet in thickness. The crude oils from all the oilsands were of the same general waxy type. There were, however, slight variations in such features as specific gravity and related front end volatility from oilsand to oilsand, and between Eakring Field and Dukes Wood. Initial well production varied from seven to as high as 375 barrels a day. The high initial productions rapidly trended downward to the lower average figure.

With this proving of good producing oilsands at a comparatively shallow depth the urge was to punch holes at the greatest speed. Dukes Wood offered road-making difficulties but the remainder of this area was reasonably amenable to fast work. There was thus a gradual transition from the initial heavy deep drilling rigs powered by steam or heavy diesels, through lighter rigs driven by electric motors powered from the grid, which could be knocked down, transported and re-built, to the final speed job consisting of unitized drilling rigs, with jack-knife portable derricks and powered by semi-diesels or electric motors. Parallel with these improvements in material there were improvements in drilling technique all towards the same end of attaining maximum drilling speed.

In 1940 the average time requirement was nine weeks for moving the rig, erecting it and drilling into the oilsand. By 1942 this had been reduced to two weeks for moving and re-erection and three weeks for drilling in, a total of five weeks. When the jack-knife portable rigs were brought into operation with their complement of specialized material the total time requirement was reduced to one week. The average time from the start of knocking down a rig on one site to its re-erection on a new site, all ready for starting drilling, was twelve hours. The record time, made in the summer, was six and a half hours. In twenty-four hours one crew broke down on one site, transported to a new site, rigged up and drilled 960 feet of hole.

The key to this speed was that all material was designed to break down into units of the largest dimensions which could be handled by the specialized transport designed for transporting them. This transport consisted of four special trucks, complete with winches and a bulldozer which did no actual transportation but aided in getting material into position. The 87-foot derrick mast let down from the vertical to the horizontal and was transported in one piece. The two semi-diesel engines and the draw-works, totalling 22 tons, were loaded in one piece on the point of balance over the rear rollers of a 15-ton truck. When off-loading this truck trended to rear like a bucking bronco with no ill effects. That is sufficient evidence to enable anyone to guess the origin of this speed work. Only one nation would load 22 tons on a 15-ton truck and get away with it; and needless to say our American friends gave most valuable service in training operators in the use of this material in Britain.

All wells on completion gave a small flow, the highest recorded initial production being 100 barrels a day. Pumping units were installed at every producing well. The pumps were operated by pumping jacks driven by individual electric motors of from 2 to 15 h.p. As the oil-gathering lines were buried this gave a clean finish to the job. Where it was desirable to tone in with the landscape the pumping unit was painted green.

The initial wells were drilled into the crest of the dome. The oil produced from these wells was water-free. As wells were drilled down-flank, water was produced with the oil up to as much as

30 per cent. This water content was reduced to 1 per cent by passing the wet oil through water separators packed with wood wool and operated at a temperature of 110°F. As a further aid 0.003 per cent of an emulsion breaker was added.

The crude oil contained a high percentage of wax and as is general in such cases there was intermittent trouble through plugging of the well tubing by high melting point wax of the ceresine type. This difficulty was overcome by devising a method of heating by electrical means the top 1000 feet of the tubing to a temperature high enough to melt the wax.

Various methods were tried out to increase production. The most promising results were obtained by using Polar blasting gelatine exploded by a delay-action device produced in Great Britain.

Eakring Field and Dukes Wood were the initial producers. They were developed into the major producers and have remained so to date.

Kelham and Caunton

If a slightly bent line is drawn from Eakring to Newark, Caunton is halfway, and Kelham is on the outskirts of Newark.

Further domes were located in these areas which, on being tested, proved to be oil-bearing. Two oilsands only were present in these domes and these were thinner than at Eakring, each being about 30 feet thick and separated by about 70 feet of shale. The Kelham and the Caunton fields were smaller in extent and in production than the Eakring field, and the production was routed through the Eakring rail sidings.

The crude produced showed the same minor variations as between the two fields and as between the oilsands. All the crude was of the same general waxy type as the crudes produced at Eakring, Hardstoft and Formby. Within this general type, however, both Kelham and Caunton crude was of a more naphthenic type and could be easily distinguished from the other crudes.

———

By the end of World War II the Anglo-Iranian Oil Company had drilled 380 wells of varying depths, covering the testing of forty-five separate structural areas. Of these 250 were producing wells. Amongst the others might be noted a deep test carried out at Eakring which did not discover any further producing oilsands below the shallow producing oilsands described above. The producers have all been covered above with the exception of a small show at Nocton, in the Eakring area, which never attained the dignity of being termed commercial. The total effort required 735,000 feet of drilling and resulted, up to the beginning of 1945, in the production of 2¼ million barrels of good quality crude oil.

Peak production was obtained in 1943 at just over 70,000 barrels a month. By the end of 1945 when the oil-bearing areas had been drilled up and the flush was off the production this had dropped to 35,000 barrels a month. At date, production is around 30,000 barrels a month.

Eakring has at all times been the major producer. Kelham produced at about 25 per cent and Caunton at about 10 per cent of Eakring. About 1 per cent would cover Formby and Hardstoft.

What of the future? Hard work with slight recompense; possibly a few more producing pimples. If one adjusts one's ideas on these lines then one will not get a false impression of the possibilities of Great Britain as an oil-producing country.

SYMPOSIUM ON COAL, PETROLEUM AND THEIR NEWER DERIVATIVES

THE Scottish sections of the Institute of Chemistry have arranged a Symposium to be held on "Coal, Petroleum and their Newer Derivatives" at the University of St. Andrews from July 7 to 12, 1947.

The Symposium is designed to give industrial scientists and others a comprehensive idea of developments which have been made in recent years in heavy organic chemistry. The first part of the Symposium deals with the raw materials and their sources, the second part with chemical syntheses, and the third part with physical chemical problems of polymerization, etc. The programme deals with the academic and industrial sides of the problem and has been arranged as follows:

I—COAL AND OIL RESOURCES

"Production of Petroleum by Synthetic Methods." Dr Kenneth Gordon (I.C.I., Billingham).
"Coal as a Chemical Raw Material, including Shale Oil, Petroleum Products, etc." (Prof. W. M. Cumming, O.B.E., Glasgow.)
"Hydro-electric Power in Scotland." A. E. MacColl, Deputy Chairman, North of Scotland Hydro-Electric Board.
"Modern Coal Gasification Developments." Dr D. T. A. Townend, Director of B.C.U.R.A.
"Petroleum as a Chemical Industry." Dr G. Egloff, Universal Oil Products Co.

II—CHEMICAL SYNTHESIS

"Polythene." Dr J. C. Swallow, Research Manager, I.C.I. (Plastics) Division.
"Nylon and Similar Derivatives." Dr R. Hill, Associate Research Manager, I.C.I. (Dyestuffs) Division.
"Vinyl Compounds." Dr J. P. Baxter, Research Manager, I.C.I.
"Acetylene Chemistry." Prof. E. R. H. Jones, Imperial College, London.
"The Fischer-Tropsch Process as a Source of Synthetic Products." (Dr C. C. Hall, Fuel Research Station.)

III—PHYSICO-CHEMICAL PROBLEMS OF POLYMERIZATION

"Polymerization." (Prof. H. W. Melville, Aberdeen.)
"Molecular Weight Determinations." (Prof. Per-olof Kinnel, University of Upsala.)
"Physical Problems and Work on Fibres." (Prof. W. T. Astbury, Leeds University.)
"The Present and Future Position in Britain." Discussion to be introduced by John Rogers, Deputy Chairman, I.C.I. Limited.

Exhibits and Demonstration of Apparatus.

The course will be spread over five days and each lecture will be followed by a short interval for discussion. On the last day there will be a general discussion and the position will be reviewed.

Applications from persons wishing to attend should be forwarded to the Secretary, Royal Institute of Chemistry, 30, Russell Square, London, W.C.1.

FUEL ECONOMY CONFERENCE

Among the papers to be submitted by the British National Committee of the World Power Conference at the Fuel Economy Conference, which is to be held at the Hague from September 2–9, is the following:

Aviation Fuel Production, by J. A. Oriel, M.C., M.A., B.Sc., F.Inst.Pet., (Chief Chemist, Shell Petroleum Co. Ltd.), and Major K Gordon, C.B.E., M.C., F.Inst.Pet., (Joint Managing Director, Imperial Chemical Industries Ltd., Billingham Division).

Full details of the programme of the Fuel Economy Conference may be obtained from the Secretary, World Power Conference, 201–2, Grand Buildings, Trafalgar Square, London, W.C.2.

Two recent and unusual photographs of the Anglo-Iranian Oil Company's operations in Persia. The top photograph shows in the foreground one of the company's residential areas at Abadan, with Abadan town beyond it and in the distance part of the refinery, which is the largest in the world. The lower photograph gives a vivid impression of the mountainous terrain in the main oilfields area, with power and pumping stations in the foreground.

RUMANIAN CRUDE OUTPUT

Crude oil production in Rumania in 1946 totalled 4,193,285 metric tons, a reduction of 9.6 per cent in comparison with the 1945 total of 4,640,000 metric tons, and of 39.6 per cent from the 6,610,000 metric tons produced in 1938. Details for various companies are given by *Moniteur du Petrole Roumain* as:

Company	*M. tons*
Astra Română	1,383,359
Concordia	502,210
Româno-Americână	490,436
Steaua Română	434,244
Colombia	290,287
Unirea	283,087
Creditul Minier	235,717
Prahova	200,508
I.R.D.P.	79,089
Others	294,348
	4,193,285

PRESENTATION TO ST. CHRISTOPHER'S CHURCH TRINIDAD

An altar frontal presented to St. Christopher's Church, Siparia, Trinidad, by Mrs Dalley in memory of her late husband, Mr Christopher Dalley, a past-president of the Institute and a former director of the Trinidad Petroleum Development Co., was dedicated at an impressive service in the church early in March.

The presentation was made by Mr Richard R. Tweed on behalf of Mrs Dalley, and the Rector, the Rev E. de Coteau, referred to the ever ready willingness of Mr Dalley to render help to the church.

At the time of Mr Dalley's death the church was in progress of building, and the natives, who are responsible for it, dedicated it to St. Christopher in memory of him. At the dedication service the church was filled, mostly with native employees of the Trinidad Petroleum Development Co.

FILM STRIP OF THE PETROLEUM INDUSTRY

The story of petroleum and its place in the modern world is the subject of a film strip published by Common Ground Ltd. (specialists in "graphic education") for instructional purposes in their series "Industrial Revolution". The strip, made up of 44 still pictures photographed on 35-millimetre film for use in a lantern type of projector, tells pictorially the history of the petroleum industry and the various activities involved in the search for, production and refining of oil and the distribution and consumption of its products. It was made by C. Cochrane of Shell-Mex and B.P. Ltd., who also wrote the teaching notes which accompany it.

The photographs include such subjects as the bitumen-bound walls of Babylon, a portrait of Dr James Young, "Father of the Petroleum Industry", Drake's well, modern views of oilfields in England, Iran and the United States, pipelines, tankers, etc., while informative diagrams show the oil producing areas of the world and world consumption of petroleum.

Many of the photographs were supplied by the Petroleum Information Bureau, and in the Bibliography acknowledgment is made to *Petroleum: 25 Years Retrospect*, published by the Institute of Petroleum.

SIR THOMAS H. HOLLAND

It is with regret that we announce the death at the age of 78 of Sir Thomas Henry Holland, K.C.S.I., K.C.I.E., F.R.S., Hon.LL.D., D.Sc., a Founder Member of the Institute and its president from 1925 to 1927.

He was director of the Geological Survey of India, 1903-9, Rector of the Imperial College, London, 1922-29, and Principal and Vice-Chancellor of the University of Edinburgh, 1929-44.

ELECTRICAL OILS AND THEIR SUBSTITUTES*

By J. C. QUAYLE, B.Eng., A.M.Inst.Pet.

EQUIPMENT

FOUR main classes of electrical equipment utilize electrical oils, namely transformers, switchgear, cables, and capacitors or condensers.

TRANSFORMERS

An oil immersed transformer consists of a core of thin steel sheets, clamped together and provided with ducts. The windings round the core consist of a number of coils of copper wire or strip, insulated from each other with cotton thread lappings and varnish, and separated from each other and from the core by cylinders and plates of compressed paper which, in many cases, are also varnished. The whole is contained in a steel tank fitted with steel pipes through which the oil circulates on the thermosyphon principal for cooling purposes when the core and coils become warm.

When the transformer is under load the core becomes warm through the rapid alternations of magnetism within it, and the coils become warmed by the current flowing in them.

On large transformers the main tank is always completely full of oil and the expansion and contraction of the oil with heat variations is accommodated by changes in level in a "breather" tank. This minimizes the area in contact with air and so lessens the oxidation which occurs from that contact. An inert gas, usually nitrogen under slight pressure, may also be used to fill the breather tank and thus further lessen the tendency of the oil to oxidation.

Ingress of moisture is most undesirable in transformers. The fibrous insulating materials absorb moisture with avidity with disastrous effects on their electrical qualities. Water not so absorbed falls to the bottom of the tank and is trapped there. To prevent moisture entering the tank the air entering the breather tank, is generally passed through silica gel or activated alumina.

SWITCHGEAR

There are many variants in the design of switchgear. In oil-immersed switchgear the main contacts are bridged by a metal bar which drops away when switching off. An arc, or flame, bridges the contacts as they open. Oil flows back, cools the flame and restores a high electrical strength to the space between the contacts.

The chamber above the switch tank, which carries the connexions, may also be oil-filled.

CABLES

A power cable is fundamentally an insulated "wire". The "wire" is of copper and has to have such a large cross section to carry large currents that if it were solid it would be stiff and intractable. It is thus made as a wire rope of many strands and three, four or five of these wire ropes are twisted together, with insulation between them, to form one cable.

The insulation consists of lappings of paper impregnated with a viscous lubricating oil of low viscosity index. If several cores are in the same cable additional impregnated paper is wrapped round them. A lead pipe is extruded over the complete assembly to retain the oil and keep out moisture. This is protected by steel wires or tapes,

*Condensed from a paper read before the Stanlow Branch of the Institute.

jute or paper wrapping, bituminous compounds, and paint.

Oil-Filled Cables

The cable under load heats up and the oil expands. If the temperature rise is great enough the lead sheath may be forced outwards. On cooling the lead sheath retains its position, giving rise to a void space in the cable. Thus a special type of cable is required for high voltage work as void spaces on high voltage work have, in many cases, given trouble in service. The void space has a lower electrical strength than the oil-impregnated paper, partial breakdown occurs, the adjacent insulation is destroyed and there is eventual total failure.

Oil-filled cables have been introduced for high voltage work. These cables contain a central duct which is filled with an oil of the spindle type. These ducts pass through compensatory reservoirs where compensation takes place for expansion and contraction of the oil. The lead sheath is reinforced with strong metal tapes which prevent plastic flow of the lead. Owing to its higher cost oil-filled cable is limited to high voltage work.

Capacitors—Oil-Filled Tank Type

A steel tank, as used for transformers, is used to contain high voltage capacitors but the internal construction is different. A large number, which may amount to several thousand, of small elements are assembled upon racks which are in turn assembled side by side in the tank. All are connected together by cabling and thus to the connexion terminals. Each element is a roll of several thin papers interleaved with thin foils wrapped tightly together. The connexions are soldered to the foils or to metal tapes laid in contact with the foils.

It is unusual to fit cooling coils in capacitor tanks as the heat to be got rid of is much smaller than in the case of transformers owing to the lower electrical losses. The design also allows for a large volume of free oil the proportion of oil to elements being as high as two to one.

An alternative design is the "box-type". Here the individual elements are flattened and packed into the container until it is approaching complete filling. This type does not permit appreciable oil circulation past the elements and hence is more suitable for small than for large capacitors. The container is usually of thin tinplate, more or less flexible. Paraffin wax, ceresine, or petroleum jelly are favoured for impregnating the box type capacitor.

ELECTRICAL OILS

All electrical equipment runs warm because of electrical losses and when mineral oils are used for cooling and/or insulating purposes they tend to oxidize.

Oxidation Resistance

The oxidation process begins, in the spindle oil type of electrical oils, with the formation of peroxide groups, with subsequent formation of aldehyde, ketone and acid radicals. The next step is one of polymerization and condensation with a further small oxygen intake, the products being resinous asphaltic bodies, progressively less soluble as cross-linking progresses. These insoluble deposits are called sludge and they have an important two-fold effect in worsening the performance of electrical gear. They fill oil ducts and cooling pipes, lessening and even preventing circulation through them. They adhere to surfaces, blanketing them and retarding heat egress. The operating temperature rises increasing in turn the rate of sludge deposition.

The sludge eventually reaches such complexity that it becomes unstable and short-chain fatty acids split off. Some of these are of such low molecular weight as to be volatile. For instance

acetic acid has been found upon corroded areas on the inside of a transformer tank lid. These low homologues are actively corrosive.

The successive formation of acid and sludge is a cyclic process and at any one moment the content of acid or sludge may show a downward trend because the rate of formation from the original oil may happen at that time to be less than the rate of decomposition. A snap test taken under these conditions would indicate a false state of improvement and it is therefore essential to have a complete record of the total oxygen ingress in order to assess the merit of an oil. This shows a consistent increase with time over a period long enough to assess the trend of the oxidation process.

The oxidation process is accelerated by contact with some metals, copper having the greatest catalytic effect and iron a lesser though measurable effect.

With temperature increase the oxidation products and processes vary. Sludge which deposits at 80°C will decompose at 150°C. The. English oxidation test which is carried out at 150 C in open vessels to accelerate results fostered the development of a highly refined oil which experience has shown to give shorter life under practical conditions than the cheaper less highly refined grade.

Resistance to Cracking

When electric power is switched off by an oil-filled switch an arc strikes between the contacts as they fly apart. The heat of the arc cracks a portion of the oil and the temperature is so high that practically all the products of the cracking are hydrogen and carbon. There are minor amounts of carbon monoxide and hydrocarbons of low molecular weight. This cracking is inevitable and there does not appear to be any difference between oils from various sources large enough to influence the choice of any particular grade or type. A transformer type oil is invariably chosen for use in switches as it possesses the correct combination of properties, low viscosity, low volatility and resistance to oxidation in the presence of metals. This is the logical choice since an oil circuit breaker often runs for weeks without being operated. Resistance to cracking is thus secondary in importance to the other properties enumerated.

Heat Transfer

In order to obtain the fastest circulation, an oil with the lowest viscosity in conjunction with a comparatively high volatility and flashpoint is needed.

Resistance to Ionization

When cable oils are bombarded by fast moving ions the molecules become activated and lose end- and side-chains as gases, notably as hydrogen and methane, while the residual valencies link up endwise and sidewise. The first result is an increase in viscosity and soon yellow deposits begin to form in thin layers which become thicker and darker in colour. This material is known as "Cheese" in England, and "Cable Wax" in the U.S.A.

Like other complex molecules with extensive cross-linking "Cheese" is resistant to solvents. The electrical strength of the deposited layers is high. Their formation is, however, attended by the generation of gas pockets where the electrical strength is low and which are subject to an undue share of the applied voltage because their permittivity or dielectric constant is about one third of that of the "Cheese". The discharges which cause the formation of the "Cheese" are fostered by the increase in gas space and become cumulatively increased until complete failure occurs.

Straight-chain bodies are more prone to form "Cheese" than cyclic molecules and thus the latter find favour as impregnants for cables and capacitors where the electrical stress is high.

Loss Factor

When alternating electrical stress is applied to an insulating material a small amount of heat is generated in it and the energy so lost is expressed in terms of the property "Loss Factor". Where oil is the impregnant in an insulation such as paper working at a high alternating stress, and especially if the frequency is also high, the heat generated may be a controlling feature in the design and oil of a low loss factor will be required. The process of oil refining removes the hydrocarbons with low resistance to degradation. These are also the hydrocarbons which have a high loss factor. However, an excessive refining treatment usually results in a fractionally better loss factor and a lower practical resistance to degradation than would result from a more moderate treatment. Excessive treatment is thus undesirable.

Solvent Action

Hydrocarbons have no solvent effect upon the materials usual in the construction of electrical equipment such as paper, wood, metals, condensation resins, oxidized-oil varnishes, and textiles. The exception is natural rubber which is rapidly swollen to a gel, especially if the oil is hot. Some of the plastics such as polystyrene and polyethylene are attacked by oils, especially when hot. Polyethylene, which is a straight-chain paraffin closely akin to paraffin wax but of 10,000 20,000 molecular weight, is apparently unaffected by naphthenic type oils up to about 60° C.

ADDITION AGENTS

Oxidation Inhibitors

A great number of substances have been mentioned in the literature as oxidation inhibitors but many of these such as the tin and chromium soaps are unsuited to electrical application, since their effect upon the electrical qualities of the oil is worse than that of the oxidation products whose formation they are intended to prevent. For transformer and switch filling oils, the higher aromatic amines such as the naphthylamines appear to offer promise. The higher phenols such as β-naphthol give a useful improvement in waxes and hydroquinone and its homologues have been recommended. Practically all these substances are, however, destroyed by electrical stress usually together with the formation of deleterious by-products. They are, therefore, inapplicable to cables and capacitors where the oil bears a severe electrical stress when the equipment is under load. Wood resin, used in cable impregnants, is claimed to give a sensible improvement in oxidation resistance.

Gas Absorbing Materials

Straight-chain paraffins are attractive impregnants for cables and capacitors in that their resistance to oxidation is high. They are unusable, however, at high stresses because they evolve gas and soon give dielectric failure,

Considerable study has been made of substances which will absorb the gas as it is formed and some promising suggestions have been made. One is for the use of naphthalene in the oil. Anthracene has also been suggested. From studies of the gas absorbing properties of oils according to the degree of refining treatment given, it is apparent that the oils themselves contain substances which have gas absorbing properties and which are removed at one stage of the treatment. The isolation and utilization of these hydrocarbons is likely to prove most valuable in promoting improvement in the gas absorbing properties of the finished oil.

SUBSTITUTES

Chlorinated Diphenyl

It has long been known that the chlorinated diphenyls show attractive

features for electrical work but their commercial development was dependent on the bulk production of diphenyl which has recently been achieved. For electrical purposes they have a number of properties which are of value and which may be summarized:

(1) Non-inflammable. The gases evolved by evaporation or arcing are non-inflammable and non-explosive;

(2) Chemically stable and inert. Prolonged service has confirmed that sludging and acidity do not occur even after long periods at 120°C;

(3) Practically immiscible with water and resist permeation. As they are denser than water any condensation remains on the surface and evaporates when conditions are suitable;

(4) Higher electrical strength than most mineral oils;

(5) Lower viscosity under working conditions than mineral oil;

(6) Permittivity nearly the same as for the solid materials used as insulation in transformers. This leads to better distribution of electrical stress, an important feature in high voltage transformers and small size capacitors.

On the other hand in some circumstances of high dielectric stress chlorinated diphenyl splits up with the formation of nascent chlorine. This attacks aluminium which is used as a component in capacitors and the resultant aluminium chloride attacks in turn the paper dielectric causing local areas of degradation which lead to early failure. Chlorinated diphenyls are also not generally suitable for switchgear applications because of the liability for objectional dissociation products such as hydrochloric acid to form in the chambers where the flow of current is interrupted. They could be used to fill bus-bar chambers but this is not considered worth while since it is necessary to use oil in the more vulnerable positions.

As the degree of chlorination increases the viscosity also increases and the solvent activity decreases. For transformer cooling it is necessary to combine low viscosity and low solvent activity and this combination of requirements is met by mixing hexachlor-diphenyl with trichlor-benzene, the favoured proportions being 60 per cent hexachlor-diphenyl to 40 per cent trichlor-benzene.

Since these synthetic liquids are necessarily much more expensive than oils it is necessary to design the enclosure tanks and cooling systems with special regard to economy of fluid. Such transformer tanks fit the core and windings closely. The tank has consequently a comparatively small surface area and large tube area. The tubes are flattened to give a high ratio of area to volume which enhances the cooling effect.

Special selection of materials and processes has been required because of the active solvent properties of the chlorinated materials.

The application of chlorinated cooling materials in transformers is limited by the extra cost to positions where transformer oil would constitute a serious hazard in the event of fire. American legislation has favoured the chlorinated cooling materials in such situations by making it expensive and inconvenient, or even impossible, to instal oil-filled units with safeguards adequate to meet the statutory requirements.

Castor Oil

Castor oil has found some use principally in the U.S.A. and Holland, as a substitute for hydrocarbons in impregnating capacitors. It permits a smaller size apparatus than do hydrocarbons, but being a chemically asymmetric body the electrical losses are

higher. Also at high temperatures the performance is poor and the material is in any case very liable to absorb moisture. For this reason and because of its comparatively high viscosity, castor oil has never found favour for cooling transformers and switch gear.

Hydrogenated Castor Oil

When castor oil is hydrogenated a waxy material is formed which is marketed on the Continent under the name of "Opal Wax". It offers the same small area advantage but its viscosity is so high that excessively high temperatures are needed for the impregnation of paper which leads to degradation of both the paper and the wax. The incorporation of liquid plasticizers, particularly hydrocarbons, to reduce its viscosity has been suggested in the patent literature but no commercial development of this possibility has yet been seen.

Poly-isobutylene

The polymers of *iso*butylene range from oily liquids to tough rubbery solids and the lower members, of molecular weight around 3000 appear to offer possibilities as substitutes for electrical oils since their composition is simple and their reproducibility is easy to achieve and check. Inspection of their characteristics indicates, however, that for capacitor impregnation they suffer the disadvantage of straight-chain paraffins, lack of resistance to electrical stress, while for transformers the viscosity temperature characteristic is flat so that thermal transfer is impeded at high temperatures more than in the case of most petroleum products.

Poly-ethylene

Here the interesting polymers are waxy solids. In fact the composition of paraffin wax is closely matched by polyethylene but the chain length of the latter is from five to twenty times as great. The increase in chain length is accompanied by an increase in toughness, viscosity and melting point and only the lower polymers of molecular weight about 5000 are usable as impregnants for capacitor dielectrics in substitution for petroleum products. For transformers and switch gear polyethylene has naturally no application as a cooling medium but it has proved to be of unique value in the specialized field of radio cables. Here it has had extensive and successful use, strongly fostered by war-time requirements, but as an impregnant the material is new and little known.

Gas and Vapours

In an endeavour to obtain higher resistance to electrical and thermal degradation gases and vapours have been tried as substitutes for mineral oils in transformers, cables, and capacitors as well as in the gas blast type of switch gear. It is claimed that gases do not deteriorate and that the usual fibrous insulating materials such as paper and cotton deteriorate much more slowly than is the case when mineral oils are used. Thus higher working temperatures are possible with consequent saving in weight and cost.

The electrical strength of gases and vapours at atmospheric pressure is much less than that of mineral oils and this has to be compensated by the use of high pressures of up to 300 p.s.i. The mechanical complexity and the expense involved in the use of such pressures militates against the use of gases, and their commercial application has been limited to high tension cables and a few high power capacitors and transformers.

The favoured gas has been nitrogen usually at about 200 p.s.i., but an interesting discovery was made concerning the refrigerant Freon, namely that at a given pressure its dielectric strength was three to four times as high as that for nitrogen. Freon is expected

to come into commercial use for this reason since it is also claimed to have adequate chemical stability.

There have been references in the literature, mainly Russian, to the similar properties of sulphur hexafluoride but so far no reference to its commercial usage has been seen.

Less likely materials such as carbon dioxide, sulphur dioxide and even superheated steam have been suggested as fluid dielectric materials and the fact that interest has been shown in these less likely materials would indicate how serious a drawback the ageing of mineral oils is considered to be by the electrical equipment industry. The implication of this state of affairs should need no emphasis to the petroleum refining industry.

SECOND CADMAN MEMORIAL LECTURE

The Second Cadman Memorial Lecture, organized by the Institute of Petroleum, is to be given at 5.30 p.m. on Wednesday, June 4, at the Royal Institution, Albemarle Street, London, W.1., when the Cadman Memorial Medallist, Mr Robert Price Russell, President of the Standard Oil Development Co., will deliver an address on "Progress in Petroleum Research". Admission is by ticket only, obtainable from the Secretary of the Institute.

On Thursday, June 5, Mr R. P. Russell will be entertained at dinner by the members of the Institute. This function is at 7.45 p.m. at the Dorchester Hotel, Park Lane, London, W.1., the reception commencing at 7.15 p.m. Tickets (30*s*. each) are obtainable from the Institute's Secretary and immediate application is advised as accommodation is limited.

The Institute of Petroleum Electrical Code. A suggested Code of Electrical Practice applicable to conditions in the petroleum industry. Published by the Institute of Petroleum, 26, Portland Place, London, W.1., pp. 77. Price : 5*s*. post free.

INTERNATIONAL CHEMICAL CONGRESS

The Eleventh International Congress of Pure and Applied Chemistry is to be held at the Imperial College of Science and Technology, South Kensington, from July 17 to 24. Section 9, Chemistry in Relation to Fuel, Power, and Transport, will be under the Chairmanship of Sir Alfred Egerton, M.A., B.Sc., F.R.S., the secretary being C. M. Cawley, O.B.E., M.Sc., Ph.D. Details of the full programme are obtainable from the Joint Press Officers, International Chemical Congress, 11, Garrick Street, London, W.C.2.

SOUTH WALES BRANCH

A meeting of the South Wales Branch was held on Thursday, April 17, 1947, at Llandarcy, the Chair being taken by the Deputy Chairman, Mr E. Thornton. Lieut.-Col. F. C. Watkins, Commandant, Army Fire Fighting Centre, Colchester, spoke on the subject of "Protecting the Army's Petrol Supply in the Burma Campaign". He dealt with the difficulties and fire hazards in connexion with the distribution of petrol and oil in the course of the Burma Campaign, how they were overcome, and the various improvisations brought into being. This was a very entertaining talk given in an easy style and much appreciated by the members.

The talk was followed by the showing of the film "The Burma Campaign" (Army version), for which members of the local Branches of the Institute of Transport joined the meeting in order to see the film.

A vote of thanks to Colonel Watkins was proposed by Mr A. S. Bruton and seconded by Mr S. J. Williams.

Modern Petroleum Technology. A comprehensive picture of the present state of technical knowledge within the petroleum industry. Published by the Institute of Petroleum, 26, Portland Place, London, W.1., pp. 466. Price : £1 1*s*. post free.

COUNCIL COMMENTARY

THERE was a good attendance at the April meeting of Council, the agenda of which dealt with the minutes and with reports from Awards, Branches, Bye-laws, Finance, Publications and Public Relations Committees.

From the Awards Committee was raised the question of having a dinner on the occasion of the Cadman Memorial Lecture. It was decided to try to stage a suitable dinner, although it was realized that it would have to be somewhat restricted owing to the limited time available.

The Branches Committee, through Mr G. H. Thornley deputizing for Mr J. A. Oriel, presented proposed rules for a new London Branch of somewhat unorthodox character as discussed in March. As was indicated in the previous report, the Branches Committee had deputed a small sub-committee, which included the representatives of the Bye-laws, Branches, and the proposed new London Branch, together with the Hon. Secretary of the Institute, to prepare such a set of rules for submission to Council. Unfortunately owing to various difficulties it was not possible to circulate the proposed rules, which were merely tabled at the Council meeting. It was decided, however, that this was such an important departure that, although reference back to the Branches Committee could be dispensed with in order to save time, it was necessary for Council at any rate to have full time to consider these rules before passing judgment, and full consideration was, therefore, deferred until the next Council meeting when it was requested that a rather fuller explanatory memorandum should also be submitted.

The Bye-laws Committee, who are reaching the final stages in the drafting and revising of the Bye-laws, drew Council's attention to three points which they considered should have separate consideration. These points dealt with the relations between President and Chairman of Council, also the position of retiring Vice-Presidents, and and interpretation of Article No. 23 as it applies to Branch nominations for membership of Council "by virtue of an office held in a Branch". The solicitors had ruled that being a member of a Branch Committee could be interpreted as holding office within the meaning of this Article and, as Council felt that it would give greater freedom to Branches in their nominations, this ruling was accepted.

The Chairman reported that he had received a satisfactory letter from Sir Donald Ferguson of the Ministry of Fuel & Power, and this might be regarded as first fruits of the work of the recently-formed Public Relations Committee.

The Publications Committee—Some discussion took place with regard to the present form and content of the new *I.P. Review* and Branches are again urged to send in matter which they consider suitable and which will interest their members.

CENTENARY CELEBRATION OF THE CHEMICAL SOCIETY

Postponed since 1941 because of the war, the celebration of the Centenary of the foundation of The Chemical Society —the first society of its kind in the world—will take place in London in July of this year. A number of meetings will be held in connexion with the celebration, and Fellows of the Society will be entertained by His Majesty's Government, The Royal Society, The University of London, Imperial Chemical Industries, and others.

THE GERMAN OIL INDUSTRY

Part I—*Pre-war Development and Wartime Performance*

By L. W. HARFORD*

No one who has not witnessed it can have any conception of the magnitude of the defeat of Germany by the Allies. Few of us have any experience of that part of post-war Germany lying East of the Elbe, but for the rest of it, the scene has been witnessed by some millions of the Allied Forces and by relatively a few Allied civilians.

It is an awe-inspiring spectacle—the spectacle of a once great nation completely broken up, thrown down and brought to naught.

No one individual could measure, or attempt to measure, the extent of the calamity which the German people have brought upon themselves. This paper is not written to emphasize the extent of the destruction brought upon the German oil industry. Its sole objective is to present an overall picture of the industry before, during, and after the war. But since it will have to trace the steps by which the industry was expanded to provide the vast quantities of oil required during the war, it must necessarily show how shattering was the collapse of the structure which the Nazis built up.

So far as the war period is concerned, the writer has relied largely upon the published Report by the U.S.S.B.S. (United States Strategic Bombing Survey) as a reference source of facts and statistics and acknowledgment is hereby made to the authors of the Survey on the oil industry. It is a monumental work and has been of the utmost value in the preparation of this paper. The account of the German oil industry post-war is based upon the writer's experience as the head of the North German Oil Control, set up shortly after the conclusion of hostilities in Germany by the British element of the Allied Control Commission.

Dawn of the Nazi Era

In the year 1933, the German consumption of petroleum products was little over 3½ million tons, the bulk of which was imported. Within five years consumption had more than doubled and plans had materially advanced towards rendering the country less and less dependant on sources outside her own frontiers.

These plans took many forms and many guises—such as the stimulation of indigenous crude oil production, the encouragement of a large refining industry, the accumulation of reserves against the day they would be required, and the encouragement of numerous forms of substitute fuels.

But towering above all these were plans for the large scale production of oil from coal and lignite.

The hydrogenation (Bergius) process had been operated on lignite on a commercial scale at Leuna in Central Germany, since 1927. The synthesis of liquid fuels from gas by the Fischer-Tropsch process was a more recent development which was not in use on a commercial scale until 1936. The technical problems of developing these processes in a very large way and making use of different types of raw material in order to provide the various products that were needed, were of course immense and were greatly increased by continual shortages in the supply both of materials and labour.

The bulk of the oil business in

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Germany was in the hands of companies whose capital was either British or American, foremost among the interested concerns being the Royal Dutch-Shell Group and the Standard Oil Company of New Jersey, with the Vacuum and Anglo-Iranian oil companies, among others, having smaller but nevertheless significant interests.

The one major 100 per cent German concern was the Benzol-Verband, representing the great coal and steel combines and works and particularly the owners of the various Ruhr and Silesian coke oven plants.

In the strictly petroleum field, German-owned concerns were dominant only in the ownership and exploitation of crude oil concessions; in this matter the German concerns, Elwerath, Deutsche Erdoel, Wintershall, and Preussag led the way.

In the matter of refineries and distribution equipment the British and American concerns held pride of place. These naturally were unwilling to collaborate in the building up of a huge synthetic oil industry in order to bring about the displacement of their own products from the German market, though at a later stage the German subsidiaries of two of these groups were obliged, by pressure from the Nazi Government, to take a share in the capital of the giant hydrogenation plant at Poelitz, near Stettin, the erection of which was begun in 1937.

Having failed to persuade the major foreign interests to co-operate in their long-term plans, the Nazis turned first to the brown coal producers and later constituted a number of agencies, in which the State held very large financial interests, to form the backbone of the future structure of the oil industry, namely the production of oil from coal. This was developed mainly in three areas: the Ruhr coalfields, the brown coal region of Central Germany, and the Upper Silesian coalfields.

Crude Oil Production

As a result of stimulus applied in various ways, and more particularly through generous drilling subsidies, there was a rapid growth in oil exploration and exploitation, resulting in increased production from around 230,000 tons in 1932 to one million tons per annum in 1940, since when production within the confines of Germany's 1938 frontiers has steadily declined.

The search for crude oil in Germany has been actively undertaken since 1880, but whilst, until the turn of the century, production was a matter of only 2000 to 3000 tons per annum, the next 30 years saw fairly steady production at higher rates, until shortly before the Nazis came to power, crude oil was being produced at a level of around 200,000 tons per annum.

Under the stimulus applied by the Nazis, production rose, as already stated, spectacularly and a number of new fields were discovered. The high level reached in 1940 was, however, accounted for in particular by flogging the valuable new field discovered at Reitbrook, a few miles outside Hamburg. The field is now almost exhausted and total German production has dropped back to the region of 600,000 tons of crude per annum.

Petroleum Refineries

At the outbreak of the war, the capacity of the German refineries—located principally in and around Hamburg—was sufficient to process roughly 3,000,000 tons per year. This figure does not include the capacity of the synthetic plants. Since her indigenous production was not in excess of 600,000 tons per year until 1939, and the refineries were running to capacity, it follows that feed stock was largely imported from abroad. In fact, much of the refining capacity was designed for

the processing and re-running of residues and partly finished products, special attention being paid to the production of lubricants, special boiling point benzines, and white spirits.

Cracking plant was available in few of the German refineries, a fact which was later in the war to prove highly embarrassing, since, with the destruction of the majority of her finishing plants, the disposal of the residues from topping, which could not be used for other purposes, provided the industry with a major problem.

The figures in Table I illustrate the nature of the operations of the German refining industry in two representative years shortly before the outbreak of the war.

Table II presents in condensed form details regarding ownership and capacity of the bulk of the pre-war refining facilities in Germany.

TABLE I

German Refinery Operations

	1935	1937
	metric tons	
Oils Treated		
Crude oil	847,800	1,172,900
Topped crude	330,400	424,400
Coal tar oils	377,900	840,600
Unfinished gasoline	137,700	205,400
Other semi-processed oils	340,100	845,800
	2,033,900	3,489,100
Products Obtained		
Benzine and gasoline	577,000	1,259,700
Kerosines	52,100	77,200
Gas and fuel oils	366,700	463,700
Crude lubricants and residues	207,100	341,700
Paraffin wax	20,200	28,000
Bitumen	406,200	582,500
Petroleum coke	43,500	68,400
Other products	236,000	530,900
	1,908,800	3,352,100

TABLE II

German Company	*Principle Shareholders*	*Annual Capacity tons*
1. Rhenania-Ossag	Shell Group	960,000
2. Ebano	Standard of New Jersey	400,000
3. Eurotank	Crusader Petroleum, London	400,000
4. (*a*) Deurag (Misburg)	Elwerath, Preussag Standard Oil and Shell	150,000
(*b*) Nerag (Misburg)	Elwarath and Preussag	150,000
5. Holsteinische-Erdolwerke	Deutsche Erdoel A. G.	150,000
6. Mawag	German	150,000
7. Deutsche Vacuum	Socony Vacuum Inc.	100,000
8. D.A.P.G.	Standard of New Jersey	175,000
9. Deutsche Gasolin	50% I.G. Farben and others* 25% Shell: 25% Standard	100,000
10. Schindler	Pure Oil Co and others	60,000
11. Schliemann	German	65,000
12. Albrecht	Shell Group	30,000
13. Wintershall	Miscellaneous German	50,000
		2,940,000

* German interests.

Distribution, as has been seen, was to a very large extent in the hands of the British and American-owned companies and of the Benzol-Verband. They owned the bulk of the distribution facilities in Germany, except for a small amount of tankage and other equipment, at Hamburg or elsewhere, owned by a number of German or foreign concerns.

Against this background the Nazis proceeded with the construction of the vast edifice of self-sufficiency in mineral oil, which the path of war passed over

and left a tumbled mass of twisted steel and rubble.

THE WAR YEARS

Synthetic Oil

By the time of the outbreak of war—September, 1939—synthetic oil production (Bergius and Fischer-Tropsch) had reached 1,280,000 metric tons per annum. The extent to which the Bergius and Fischer-Tropsch plants contributed to Germany's oil supplies during the course of the war, is clearly shown in Fig. 1, compiled from the U.S.S.B.S. Report, to which reference and acknowledgment has already been made. For ready reference, the figures representing total production of liquid fuels and liquefied gases by these processes are as follows:

	Bergius Process.	*Fischer-Tropsch.*	*Total*
	Thousand metric tons		
1940	1,504	449	1,953
1941	2,107	474	2,581
1942	2,772	446	3,218
1943	3,431	484	3,915
1944 per annum rate for 1st quarter	3,780	508	4,288
Total 1944	1,875	306	2,181

It is probably not generally realized that the Bergius plants provided the Nazis with over 99 per cent of their wartime supplies of aviation gasoline—supplies which ranged from a maximum of about 150,000 tons per month to a mere trickle by the end of the Allied air offensive against the oil targets, by which time every single synthetic oil plant had been knocked out.

At peak, the synthetic oil plants provided slightly under 50 per cent of Germany's total supplies of oil.

German Crude Oil Production—1940–44

From the same U.S. source, the following figures of production may be quoted:

	Alt Reich	*Austria*	*Total*
	Metric tons		
1940	1,052,000	413,000	1,465,000
1941	927,000*	635,000	1,562,000
1942	817,000*	869,000	1,686,000
1943	776,000*	1,107,000	1,883,000
Per annum rate for 1st quarter 1944	768,000*	1,195,000	1,963,000

* Including Pechelbronn from July 1st, 1941 (about 60,000 metric tons per annum)

The steady decline, due in part to wasteful production methods in 1940, and in part to lack of balance between exploration and exploitation drilling, in the Alt Reich will be noticed—as also the fact that this was more than offset by increased production in the Danube basin.

Loot

Details will be given later in this paper of the precarious position of Germany's stocks of oil when the Fuehrer, in defiance of his experts, military and other, plunged headlong into war towards the end of 1939. Her overwhelming defeat of France and the Low Countries in the spring and early summer of the following year won her a prize in loot and booty of almost the entire stocks of oil laboriously built up by these countries. It was indeed a tragedy for the Allies that these very substantial stocks, totalling anything from 1½ to 2 million tons in aggregate, should fall a prize to the German Forces, thus tiding her over what would otherwise have been a period of the most critical shortages until her war production had got into its stride.

It is known that in this way Germany secured an addition of not less than 245,000 tons to her slender resources of aviation gasoline, and it is a particularly bitter fact that this was to provide a substantial proportion of the fuel consumed by the Luftwaffe in the Battle of

Britain — which was launched a few months after the defeat of France and the Low Countries.

The German Shortage of Oil

Most oil men will have a vivid recollection of the constant "estimates" throughout the five long years of the war, of inspired and uninspired prophets and others as to the number of days, weeks, or months German oil supplies would last before the entire war machine would come to a grinding halt for lack of oil. To many it seemed that Hitler, by means of the powers of evil, was giving a very successful imitation, on a gigantic scale, of Elijah's solution of the oil supply problem in another wilderness some time ago.

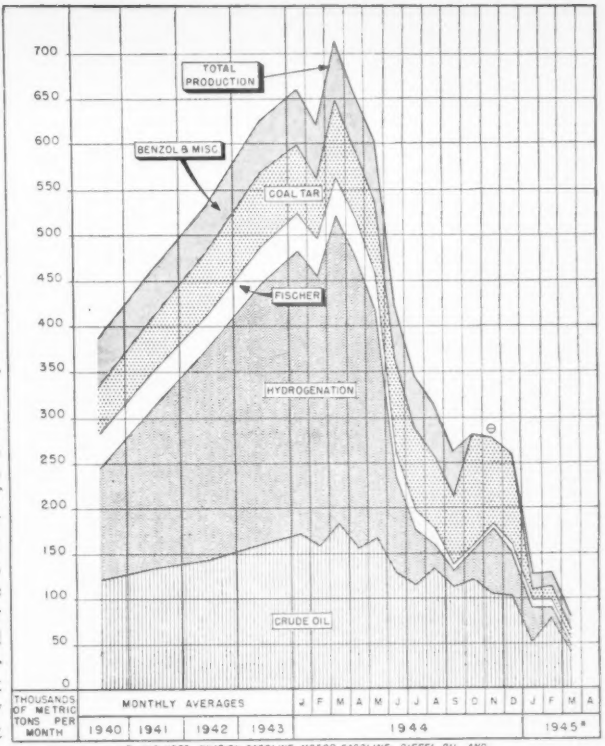

Fig. 1.—German Production of Petroleum Products by Process, 1940–1945

Yet the steadily mounting production, month by month and year by year, for the first four years of war, which will be seen from Fig. 1, must come as something of a shock to many experts.

Were there then no dark days? Were the Nazis blissfully ignorant of an oil supply problem? Were there always abundant supplies for all their offensives and in due course for their long drawn out retreats and rearguard actions?

The throwing open of the German records to the exhaustive and critical examination by experts, and the possibility of interrogating those who were responsible for the achievement of the seemingly impossible, has revealed something of the bitter struggle to which the Germans were put throughout the war and the immense cost at which her mounting production was obtained.

The report of the United States Strategic Bombing Survey shows the desperate straits in which the Germans did in fact frequently find themselves. There were periods during which the fighting services literally ran out of oil

and civilian consumption was reduced to almost unbelievably low levels. There is no doubt that German strategy was conditioned by the forward estimates of her oil stocks and German tactics were often affected by the actual stock level at a particular time. It will be realized that such stock levels must have imposed untold difficulties upon the planners, the fighting forces and their supply services, and in fact upon the whole German economy.

Table III shows in detail the stock level of German supplies of aviation gasoline at various periods of the war. It will be seen that the peak figure was 680,000 tons in July 1940, and the lowest level (except at the time of the ultimate collapse when storage tanks were all but dry) was 200,000 tons in August, 1942, when the Germans started their long and ultimately ineffective siege of Stalingrad.

TABLE III

Aviation Gasoline Stocks

		Metric tons
1940		
April–May	Invasion of Denmark, Norway and the Low Countries	500,000
July	Following on surrender of France	680,000
1941		
June	Invasion of Russia ..	500,000
December	End of Moscow siege	250,000
1942		
August	Start siege of Stalingrad	200,000
October	El Alamein	275,000
November	Allied landings in N. Africa	300,000
1943		
May	End of resistance in N. Africa	300,000
September	Surrender of Italy ..	300,000
1944		
January	Russian offensive under way	440,000
May	Allies preparing to open "Second Front"	575,000
June	Allied landings in Normandy	475,000
July	Fall of Paris to the Allies	275,000
September	Decision to put oil plant underground	230,000
1945		
January	Nearing the end ..	140,000

N.B. Consumption ran between roughly 100/200,000 tons per month until September, 1944, when it dropped sharply.

GERMAN WAR RESERVE STOCKS

Reference has already been made to the critically low stocks of oil which Germany held, when she plunged into war against Poland. In fact, one of the most illuminating disclosures which have resulted from the Allied examination of the German war records and the interrogation of the high officials and Service personnel concerned with such matters, is in regard to the level of these stocks, as to which it will be remembered there was so much speculation on the part of the Allies, when once the war had been joined in earnest.

It transpires that on August 1, 1939, Germany's total stocks of oil in the country were not more than 2,134,000 tons, or, roughly, sufficient for four months' normal civilian consumption on a pre-war basis.

Only in the case of lubricating oil and diesel oil for her submarines did Germany hold substantial stocks; her stock of aviation gasoline and motor spirit was insufficient to last, with other sources closed down, for more than a few months.

The evidence is abundant, firstly, that Hitler precipitated war long before the planners were prepared for it and secondly, that he staked everything on the war being of very short duration.

As a single illustration of the range to which the planners had been working, it may be pointed out that whilst in September, 1939, the completed capacity of the synthetic oil plants was just under one and a half million tons per annum, the actual output of the synthetic plants in 1942 was over double this figure, viz., 3,200,000 tons. The maximum output achieved was reached in April, 1944, and was at a rate

slightly in excess of 4,000,000 tons per annum, but the designed capacity of the plants then in operation, or under construction aggregated nearly 5,000,000 tons per annum.

Aids to Reduced Consumption of Petroleum

The Nazis were disappointed in the development of the producer gas generator as a means of economizing consumption of petroleum. Nevertheless, the use of gas generators accounted for an economy of something like 700,000 tons of liquid fuel per annum (civil and military consumption combined) during the last two years of the war.

Coal tar products, naturally available in increasing quantities with the extensive development of steel production and other industries, provided valuable additions to supply, e.g.:

Benzol: about 400,000 tons per annum,
High temperature and low temperature, tars used as fuels: from one-half to one million tons per annum,

whilst there was a considerable extension of vehicles operating on town gas.

Thus, it is seen that Germany was able to replace petroleum by other and more readily available products to the extent of about 2,300,000 tons per annum—or the equivalent of 230 tanker voyages per year expressed in the measure that meant so much to the Allies.

Civilian Consumption

The progressive and drastic restriction on the civilian consumption of automotive fuels is illustrated by the following figures of civilian consumption:

	1,000 *metric tons**	*Index*
Pre-war	4,008	100
1940	2,105	53
1941	1,905	48
1942	1,440	36
1943	1 513	38
1944	1,312	33

* Including equivalent tonnage of substitute fuels.

Bombing of Oil Targets

Whilst it is not intended here to examine Allied policy in regard to the bombing of oil targets, all experts appear to agree that it was not until the spring of 1944 that the Allies had developed sufficient striking power and superiority over the enemy's defences to be able seriously to affect output from the oil plants.

When once the required build-up and superiority had been obtained the attack on the oil targets was let loose with devastating effect. But the effect was only obtained by striking again and again and again. Experience showed with what amazing pertinacity and skill the Germans set to work after each attack to get plant back into production once more. Experience showed, moreover, how extremely difficult it was to knock out plant beyond the hope of recovery, more especially heavy plant in the synthetic oil works.

The post-war examination of all matters concerning the bombing of oil plant has produced a mass of evidence from which no doubt valuable conclusions are to be drawn by the experts. An interesting sidelight is incidentally thrown on the accuracy of Allied intelligence. The Germans suspected leakage of information as to anticipated dates on which plant would come back into production, in that almost invariably within two to three days after production had been restored—in some cases after months of herculean effort—the Allies came over and pounded it out of production again. The efforts to prevent or minimize leakage of information were so little successful that in the later stages of the bombing, Speer, Reichsminister for Armaments and War Production, is reported as petulantly complaining to the Fuehrer that plant was being bombed—2 to 3 days *before* it was due to come back into production.

To a certain Herr Geilenberg, armed by the Fuehrer with almost unlimited

power and authority, is due the major credit for the work of repairs to the bombed oil plant—and more especially the bombed synthetic oil plant.

The expenditure of manpower, materials and coal on the production of oil from that product is at all times heavy. The U.S.S.B.S. makes the neat comparison that "the quantity of gas used per day in four average Fischer-Tropsch plants would supply the whole of New York City for the same period." Nevertheless this expenditure was ultimately eclipsed by that of the Arbeitsstab-Geilenberg, which at one time accounted for about 300,000 men on bomb damage repair work. The material and stores that went into the work of repair was of course on an equivalent scale and imposed an immense burden on the State economy, by now strained to bursting point.

Plan to Disperse Plants too Late

In view of the elaborate nature of the plans which had been developed by the end of the year it is almost unbelievable that it was not until September, 1944, that the decision was taken by the Nazis to disperse their oil plants and put whatever they could underground.

The effects of the Allied bombing, when once the required build-up had been obtained, and the decision taken for an all-out attack on Germany's oil supplies, were devastating. By the middle of 1944, stocks and production had been reduced to disastrously low levels and the drain upon Germany's resources, now pressed from every side, caused by the gigantic repair projects at the synthetic oil plants and refineries, had reached climax.

After heated and protracted controversy, the decision to go underground was taken. But the decision imposed a still further strain on the German economy, now fast approaching disintegration, for the most elaborate and fantastic plans were devised in a last desperate effort to produce the vital supplies of oil without which the entire German Forces would inevitably collapse.

In the initiation and execution of these plans, the German oil technicians excelled themselves and no one who has visited one of the more elaborate of the dispersed plants—such as the lubricating oil plant at Porta just outside Minden in Wesphalia will ever forget the experience. It is almost of Jules Verne conception and its execution within the very limited time can only have been achieved by the employment of methods akin to those utilized by the Japanese in Siam.

The Nazis managed to maintain a very considerable degree of "security" in regard to their dispersal plans, and it was not until the Allies had penetrated well into the heart of the country that full details of the plans were obtained. Obscure references to "cuckoos" and "doves" and "badgers" had been intercepted by the Allies, but with little clue as to the identity hidden behind the names of these creatures. In fact plans had been developed for the dispersal and concealed or underground construction of no less than 100 plants, ranging from small topping plants to complete hydrogenation plant. The multiplicity of plant type can well be seen from the following list, showing the Code Word used to denote each particular type of plant:

OFEN	Crude distillation unit.
DACHS	Lubricating oil plant.
KUCKUCK	Hydrogenation, hydroforming, catalytic cracking.
SCHWALBE	Hydrogenation.
ROST	Primitive crude distillation unit.
KARPFEN	Small Fischer-Tropsch plant.
WUESTE	Shale oil plant.
MOLCH	Phenol extraction plant.
TAUBE, JACOB	Cracking plant.

and numerous other individual types of plant.

It will be seen that this was a most

formidable undertaking and indeed it was too late to be capable of fulfilment at this stage in the war. Despite all the ingenuity shown from every angle, whether in design, lay-out, location, construction or camouflage, only a trickle of oil was produced, and that largely from the crude topping plants, before the end came with the total collapse of all resistance.

All the dispersed plants of interest were visited and inspected by the British and American teams of experts whose reports have been published by H.M. Stationery Office. So far as the writer knows the plants have unfortunately been allowed to go to rack and ruin with no effective effort made to secure anything out of the wreck, whether for German or Allied purpose. Like the rest of their plans, which so nearly might have succeeded, the Nazi plans for self-sufficiency in oil finally crumbled into the dust.

(To be concluded)

PERSONAL NOTES

Prof F. H. Garner, O.B.E., has been appointed a member of the Fuel Research Board of the Department of Scientific and Industrial Research.

Max W. Ball, recently appointed director of the Oil and Gas Division of the U.S. Department of the Interior, served during the war with the Petroleum Administration for War as special assistant to the deputy administrator. Prior to this he had been in consulting practice since 1928.

Doyle D. Buttolph, newly appointed manager for the Mechanical Equipment Division of Phillips Petroleum Co., Bartlesville, joined the company in 1940 as senior draftsman. In 1941 he was acting-district manager of the Tank Car Division. He subsequently served for nearly four years in the U.S. Army, and on his discharge became assistant manager of the division of which he is now manager.

Dr Roy Cross, who died on March 21, was well known for his work on a cracking process and as the author of *A Handbook of Petroleum, Asphalt and Natural Gas*. This book was published as Bulletin 25 of the Kansas City Testing Laboratory, of which Dr Cross was president.

T. Davidson Pratt, C.B.E., M.A., director and secretary of the Association of British Chemical Manufacturers, has been awarded the American Medal of Freedom with silver palms for exceptionally meritorious work and co-operation with the United States while Controller of Chemical Defence Development at the Ministry of Supply, 1940 to 1945.

R. G. Searight, who recently succeeded D. R. Mackintosh as general manager of the Shell Co. of Egypt Ltd., and of the Anglo-Egyptian Oilfields Ltd., was civilian oil adviser to the Petroleum Section of A.F.H.Q. from August, 1904, until early in 1945. He has been associated with the Shell group since 1928.

FORTHCOMING MEETINGS

INSTITUTE MEETINGS

The Use of Petroleum Products in the Printing Ink and Allied Industries. Dr A. C. Healey and Dr L. Ivanovszky. At 26, Portland Place, London, W.1. 5 p.m. June 11.

Progress in Petroleum Research. R. Price Russell. Cadman Memorial Lecture. At Royal Institution, Albemarle Street, London, W.1. 5 p.m. June 4.

Dinner in Honour of R. Price Russell. Dorchester Hotel, London. 7.15 p.m. for 7.45 p.m. June 5.

PUBLIC RELATIONS AND THE PETROLEUM INDUSTRY

By A. H. T. CHISHOLM, C.B.E., M.Inst.Pet.

MARK TWAIN, the great American humourist, is credited with remarking that the weather is something that people talk about and often complain about but nobody does anything about. The same can be said of the Public Relations of the Petroleum Industry, at any rate so far as Great Britain is concerned; for something is certainly being done about them in the United States, as mentioned below. In Great Britain these relations resemble some of the less near and dear of our own families, those distant cousins who are only rallied round at rare family gatherings or emergencies.

This may be because the real nature of Public Relations, like the origin of crude petroleum, defies definition. Such at any rate was the conclusion of the principal speaker at the American Petroleum Institute's full dress debate on the subject at Chicago in November, 1945. "Anybody who talks about public relations is expected first to define it," said he. "I have come to the conclusion that there aren't two men in this room who would agree on the same definition of public relations, so let's skip it." In brief, however, and for the purposes of this article, the Public Relations of our or of any other industry may be taken as being the activities of that industry which are directed towards correctly informing the public (i.e., the world at large including, of course, many persons intimately connected with the industry itself as, for instance, employees or shareholders) about its own history, doings and aims.

The debate of the American Petroleum Institute referred to above resulted in general agreement that, by and large, a "public-opinion vacuum" existed regarding the industry, which it was desirable to fill with correct information; for otherwise, as is the way with vacuua, it was just as likely to suck in wrong ideas. In consequence more than 35,000 concerns in all branches of the American petroleum industry have since been stimulated into a more active public relations programme, with the A.P.I. itself taking a vigorous lead through an *ad hoc* committee.

So far as the petroleum industry of Great Britain is concerned no such intensive activity is afoot in this particular field. Nor indeed is the time ripe or propitious for it with paper-shortage and printing bottlenecks exercising their cramping influence not only on newspapers of all sorts but on every form of paper-information medium from book to brochure. And apart from the printed word in its various forms, which play so large a role in the apparatus of public information, the radio, cinema and lecture, with their various appeals to the ear and the eye, are similarly circumscribed for us in a way happily unknown to our American cousins. But there undoubtedly is a feeling in petroleum industry circles that if before the war, when time, space, men and material for such activity were so freely available, they had been more generously used, the industry would now have a better showing in, for instance, the British and world Press, than it actually does. A "better" showing, incidentally, in this connexion means a "correcter" showing, for no one will deny that the petroleum industry, whether in its simpler aspects such as the petrol ration or oil-coal conversion, or in the comparative subtleties of the

petroleum-chemical industry or such speculations as "will atomic energy supersede oil", gets its fair share, or perhaps more, of the headlines. But those who know the industry from inside only too often find that what comes under those headlines does not give the correct or most interesting story. And this gives rise to qualms that the industry in general may have been backward in coming forward to inform the public about itself in the days when it was easy to do so; and to good resolutions that now may be the time to plan a more open and forward policy in this respect in readiness for when space and time are more available to reward it. For of two things there is no doubt; firstly that a widely and correctly informed public opinion must be a good thing for any sound industrial or commercial activity, and vice versa; and secondly that the petroleum industry of Great Britain is not only sound, but also, quite apart from the brave showing which its war medals make on the rare occasions when British reticence is accustomed to permit their display, an increasingly vital factor in the industrial, commercial and general economy of our country and commonwealth.

The public relations of an industry, or its public information services in the broad sense described above, fall into two important categories, and two important sub-divisions. The two categories are information about the industry as a whole and information about its particular units or concerns; the two sub-divisions are information supplied in response to demand and information volunteered; the latter sub-division includes advertising, which must therefore be included in any broad consideration of public relations although it is in itself so wide a field as to merit consideration as a subject apart.

It is probably in the sphere of "information supplied in response to demand" that our petroleum industry can under present conditions of prevailing public interest begin to make best headway towards filling the public-opinion vacuum here which with little doubt parallels that which the A.P.I. has discovered on the other side of the Atlantic. How this had best be done is a matter for considerable thought and argument even amongst those who are all agreed on a more "unsealed lips" policy. Some may favour referring enquiries about the industry in general to a central institute, bureau or agency constituted for this particular purpose; others may feel that this will lead to too stereotyped or inhuman an impression being given and advocate the widest possible individuality of reply. As regards enquiries about particular units or concerns, some will advocate canalizing these through one "spokesman" branch or individual in each unit, while others would endeavour to put the enquirer himself into direct touch with their best expert on the subject under investigation. But from the point of view of the petroleum industry as a whole these are matters of detail which will work themselves out with comparatively little difficulty once the die is cast "to be or not to be" better known to the general public and to act accordingly. If the "to be's" have it, it will entail new calls on manpower and material, and these must be weighed against other calls and the value set on changing from such "not to be" ways as are admitted. It is a nice study in intangibles, for which it is not the object of this article to propound any "school solution", if only because such solutions are too often only applicable to academic questions and not to those constantly arising in the cold hard school of highly progressive industry. But "to see ourselves as others see us" being so well accepted as a healthful exercise, and "public relations" being an important element in our mirror, we will probably be well advised to follow our American colleagues in giving them some thought at this time.

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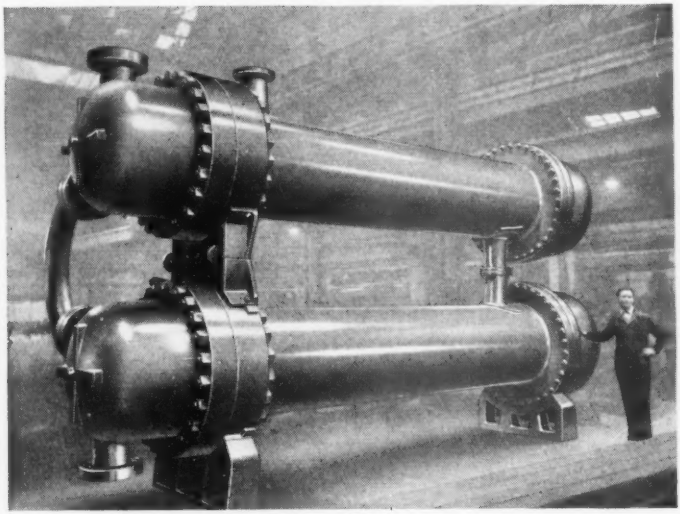

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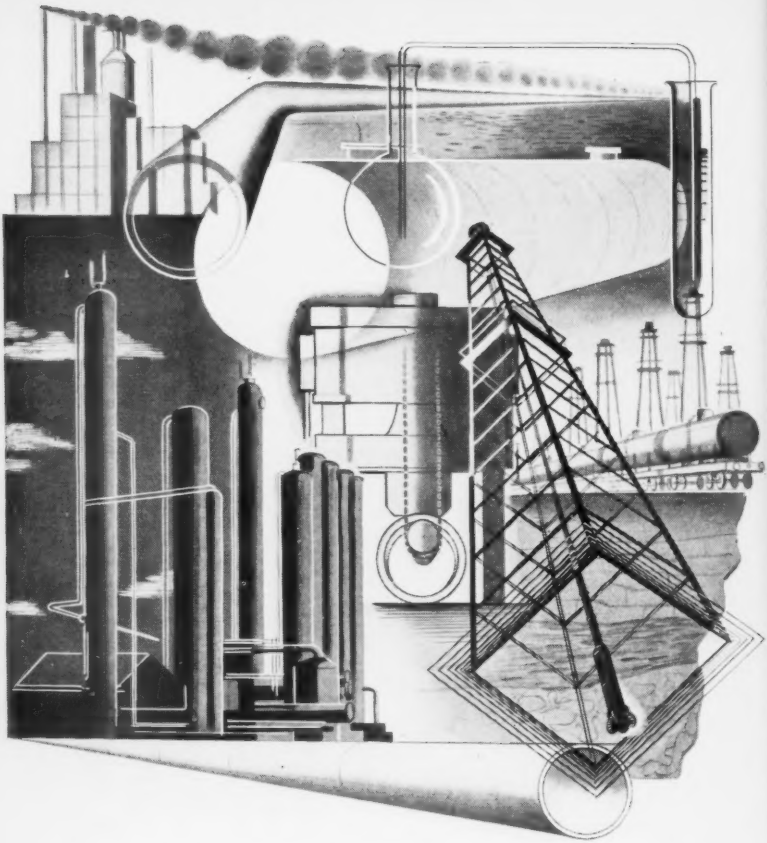

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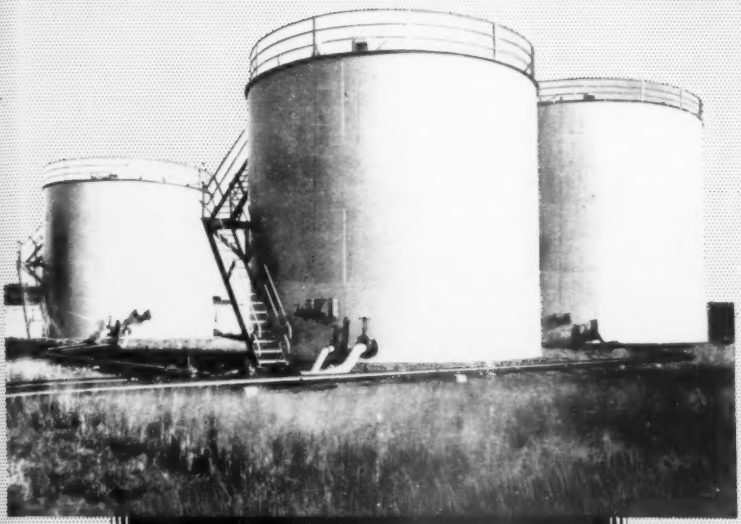

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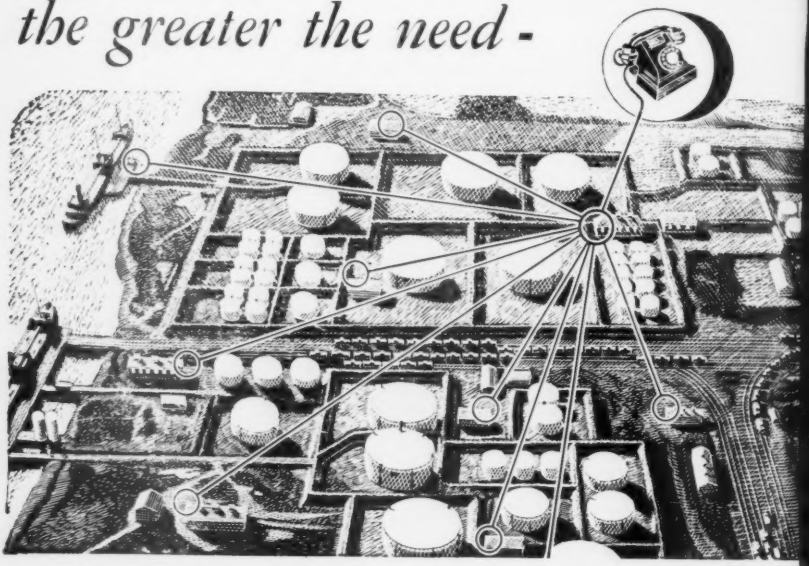

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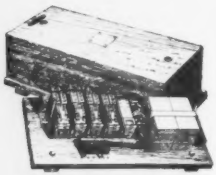

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